ERGONOMICS DEMONSTRATION PROJECT

Carpentry, Laborers, Rebar And Concrete finishing

December 2001

Department of LABOR AND INDUSTRIES

Ergonomics Demonstration Projects in Carpentry, Laborers, Rebar and Concrete Finishing

Department of Labor and Industries, December 2001

Conducted in Conjunction with Ferguson Construction and GLY Construction

These ergonomics demonstration projects were initiated during the first half of 2001 with two larger commercial contractors. The Ferguson and GLY projects are independent and had different goals. However, both focused on identifying Hazard Zone risk factors and technically feasible solutions for the major tasks and non-specialty trades associated with commercial concrete building construction. The Ferguson demonstration project focused on identifying Hazard Zone risk factors and technically feasible solutions for carpenters, rebar workers, and concrete finishers. Risk factors were quantified by work sampling using a checklist based on the Ergonomics Rule risk factors. The GLY project is still being conducted, and focuses on identifying Hazard Zone risk factors for carpenters and laborers. Additionally, the GLY project will include field testing of possible best practices and assessment of the utility of identifying potential hazards by task and using scheduled weekly safety meetings.

The following is a summary of the information gained on Hazard Zone risk factors and technically feasible solutions for carpenters, laborers, rebar workers, and concrete finishers performing construction of commercial concrete buildings.

Carpenters

More than 500 samples were taken of carpenters working on different types of formwork. The primary risk factors of concern were found to be back bending greater than 45 degrees for more than two hours, and heavy lifting. Generally, carpenters performed varied tasks, which reduced the exposure to any one risk factor.

Back bending was observed as a *potential* Hazard Zone risk factor when constructing deck forms and other floor level work during the whole day. No Hazard Zone risk factors were observed for workers constructing supports; however, this was done on both sites using new aluminum deck systems. Higher levels of risk factors may be present in older systems using wood beams. Back bending was above the Hazard Zone level for deck sheeting work; however, limited modifications could bring it down from the observed 32% of the eight-hour day to the goal of 25% or below.

Lifting material and equipment was an infrequently observed Hazard Zone risk factor. Lifting material over 90 lbs. or lifting heavy material such as HDO plywood incorrectly from the ground was observed in some cases. Carpenters usually did not lift hazardous weights when moving multiple pieces of material; however, people may sometimes lift more material than is safe when in a hurry or to reduce the number of trips. In almost all cases, heavy lifting is easily mitigated

either by using mechanical equipment, by getting help from another worker, or by positioning and lifting the material correctly. Table 1 summarizes the Hazard Zone risk factors and solutions by task for carpenters.

Figure 1. Common formwork tasks evaluated during the ergonomics demonstration projects in commercial concrete building construction (Clockwise from top left: installation of gang forms, positioning a column form, building gang forms, construction of deck forms).

Table 1. Potential Hazard Zone Risk Factors and Solutions for Carpenters by Task

Risk Factor	Possible Hazard Zone Tasks	Mitigating Solutions
Heavy Lifting > 90 lbs or > 70 lbs From Ground	Moving equipment (ie. compressors)	1) Use mechanical equipment such as cranes, forklifts or backhoes. 2) Get help from another worker if mechanical aid is not available.
	Moving material (ie. lumber, beams and plywood)	1) Use mechanical equipment if one piece of material is > 90 lbs. 2) Get help from another worker if mechanical aid is not available if > 90 lbs. 3) Limit loads of multiple pieces of material to 70 lbs or less. 4) Loads up to 90 lbs may be lifted occasionally if using walk-up/tilt-up technique. 5) For frequent lifts > 70 lbs, place load close to work location and use pallet jacks or slide material when possible.
Back Bending > 45 Deg. More Than 2 Hours/Day	Intalling deck form sheeting	1) Use nail-gun handle extension to secure decking (still under investigation). 2) Rotate to perform deck support installation for 1/2 of the day. 3) Use saw horses, or raised material to cut plywood.*
	Constructing gang forms	1a) Use a screw-gun with handle extension to secure sheeting. 1b) Construct most forms raised at least 20 inches from the ground. 1c) Perform cuts on saw horses or on plywood stack.

*Indicates a recommended practice that may not be feasible in some cases or that may not reduce the risk factor below the Hazard Zone

Examples of Mitigating Solutions for Carpenter Hazard Zone Risk Factors

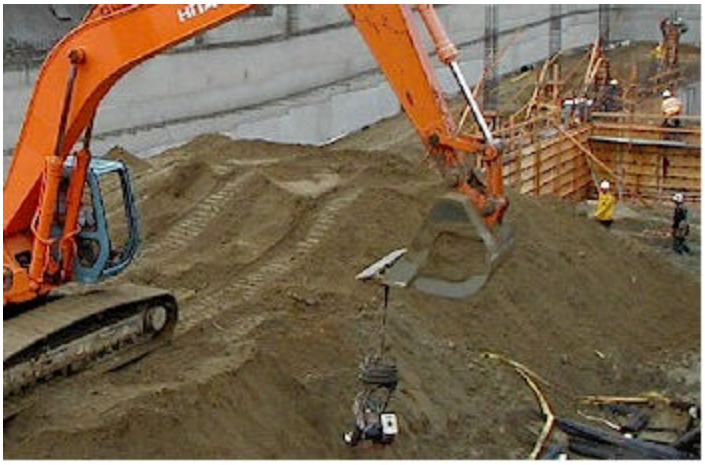

Figure 2. Heavy equipment and materials can be lifted into location by cranes, forklifts, mobile lifts, boom trucks or other machines such as the pictured backhoe moving a generator.

Figure 3. When pieces of heavy material need to be moved a short distance and mechanical lifting is not feasible, using a two-person lift can be very effective.

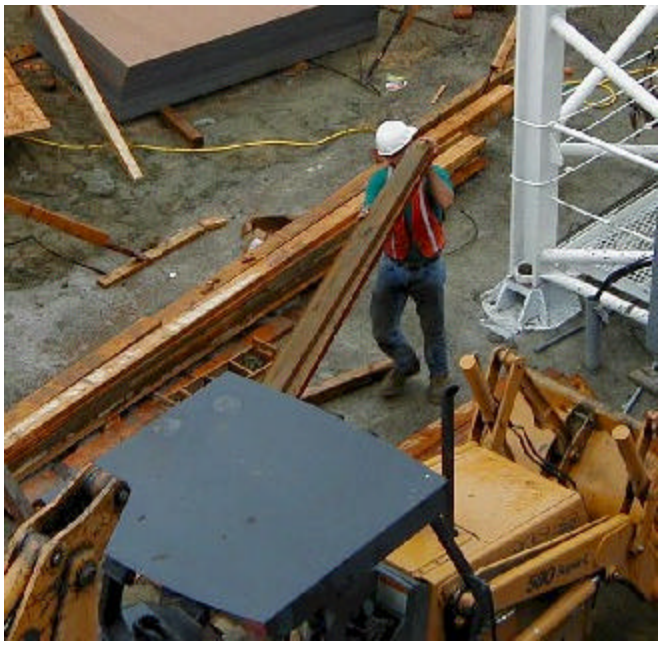

Figure 4. A carpenter using the walk-up technique to lift boards up onto the shoulder. Lifting this way instead of all at once from the ground, increases the weight that can be lifted. Lifting should be limited to a maximum 90 lbs if lifted from above ground level, as is the case with a walk-up lift. Examples of maximum acceptable lifts include: Two 10 ft. 4x4s, Three 10 ft. 2x6s, or One sheet of plywood.

Figure 5. This picture shows a carpenter on the left sliding plywood from a well-located stack to a pallet jack without lifting the full weight of the material. The carpenter on the right is using the tilt-up technique to raise the height of the effective lift for the plywood before lifting it onto a sawhorse.

Figure 6. Simple support stands can be used to raise material and equipment from ground level, making lifting easier and raising the weight that can be lifted.

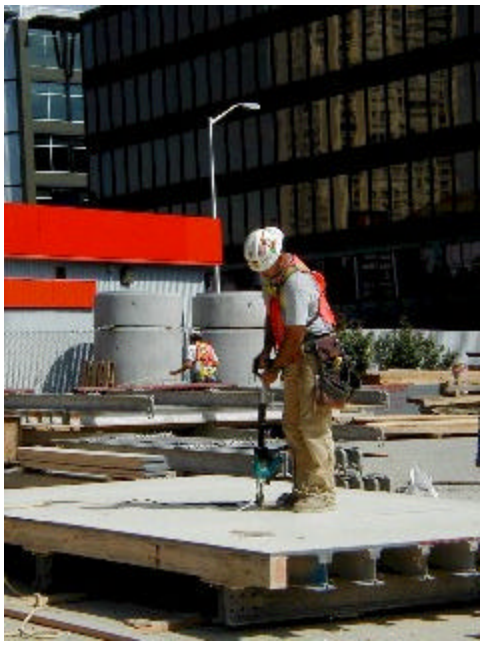

Figure 7. Screw-gun handle extensions are widely available and used in applications such as securing gang form sheeting. This simple modification reduces back bending during repetitive fastening activities.

Figure 8. Nail-guns are also available with handle extensions. These nail-guns have been used successfully in roofing (roofing washer attachment shown) and can also be used for floorwork and other types of carpentry. Currently the handle extension shown is available for Hitachi nail-guns, though others are expected on the market.

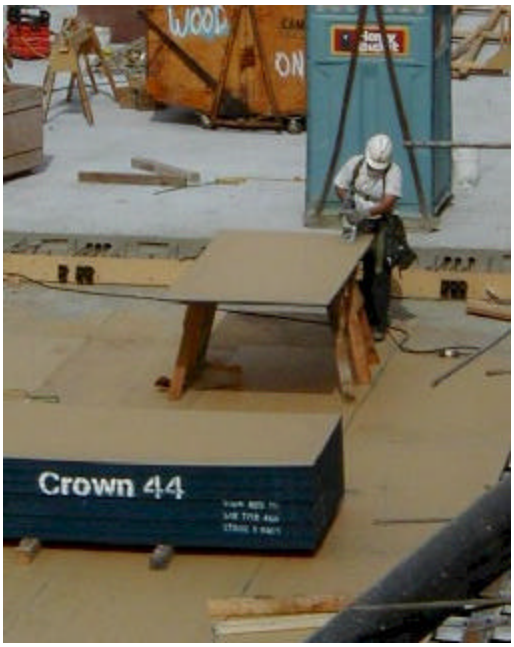

Figure 9. Raising the work level to perform detail work or make cuts can reduce the duration of back bending.

Laborers

Laborers were observed at the GLY site only. Typical tasks observed included: soil preparation and compaction, pouring concrete, and spraying concrete slabs. Several hundred work samples were recorded of laborer tasks with the exception of soil compaction. No Hazard Zone risk factors were observed during concrete-related activities for laborers at this site. Soil compaction was performed using self-supporting soil compactors, which are not covered for hand-arm vibration under the Ergonomics Rule. However, if soil compactors that are not self-supporting are used, then hand-arm vibration exposure would need to be limited to levels below the Hazard Zone described in Appendix B. Exposure can often be limited by task rotation, choosing a tool with less vibration, or by provision of anti-vibration gloves if no other alternatives are feasible.

High hand force with awkward postures may be possible if shoveling or trenching were performed all day on multiple days, however this was not observed at the demonstration project sites. Another possible Hazard Zone risk factor, though also not observed in this case, could be using a chipping hammer for extended periods on multiple days. As with a non-supporting soil compactor, the amount of time a worker can use the tool depends on the declared level of hand-arm vibration from that specific tool. High vibration tools such as chipping hammers may be above the Hazard Zone level if workers are using them regularly for more than half the day. However, each tool used regularly above the Caution Zone levels of 30 minutes total duration for high vibration tools or 2 hours for moderate vibration tools, should be looked at individually to make sure they really do exceed the Hazard Zone level as used.

Figure 10. Laborers performing soil compaction using a jumping jack (left) and walk-behind soil compactor (right).

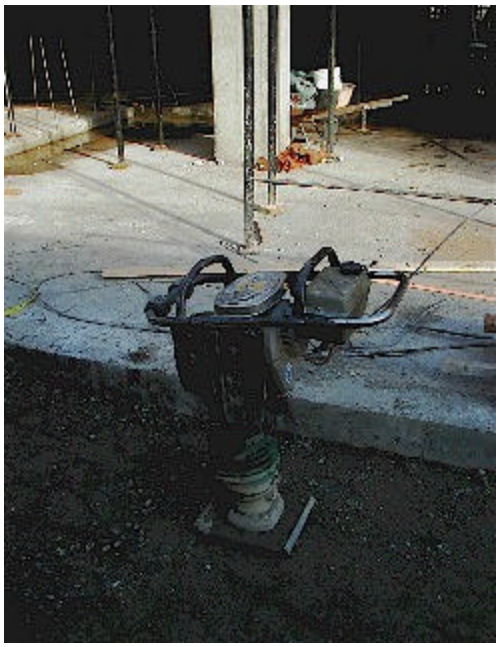

Figure 11. Jumping jacks or other equipment used for soil compaction that are self-supporting, such as this one, are not considered under the Ergonomics Rule for hand-arm vibration. Jumping jacks that are not self-supporting are covered under the Ergonomics Rule and exposure to those tools, if a self-supporting tool is not feasible, must be limited to levels below the Hazard Zone detailed in Appendix B of the Ergonomics Rule. Jumping jacks should either be moved by pushing while the tool is on, lifting with two people, or by mechanical means such as a crane.

Re-bar Work

Over 300 samples of workers constructing different re-bar systems were observed at one Ferguson site. Workers were observed installing re-bar for footings, slabs, columns and vertical walls. Several Hazard Zone risk factors were identified for re-bar work. Heavy lifting of rods is a *potential* Hazard Zone risk factor, though it can be controlled by using mechanical aides such as cranes and forklifts whenever possible and by eliminating lifting too many rods. Rods can easily be raised from the ground by placing them on support stands pictured in figure 12, increasing the maximum acceptable weight to 90 lbs. Tables 3 and 4 show the number of re-bar rods by bar# and length that can be lifted from the ground (70 lb max) or if raised (90 lb max). Twice as many rods can be lifted at one time if done as a two-person lift.

Back bending and high force with repetition and awkward posture are also probable Hazard Zone risk factors while tying rebar. These are very difficult risk factors to control due to the location of the work and current method for tying. Using support stands for columns and other components can help reduce back bending and should always be used where applicable. Both back bending and high force with repetition were observed at just above the Hazard Zone level of 2 hours per day. So even limited mitigation of these risk factors may reduce them below the Hazard Zone level on average.

Re-bar tying tools exist that can reduce the amount of back bending and high hand force with repetition. One of these tools is currently being evaluated in the field. These powered tools are fairly new on the market but show promise for some applications and may be applicable to more types of construction in the future. Currently they can tie up to #5 or #6 rebar so they are primarily for repetitive mat tying, where they are as fast or faster than manual tying. Concerns of cost, reliability and strength will be evaluated in the field, but even limited application of these tools on-site can reduce these risk factors below the Hazard Zone level.

Figure 12. A re-bar worker tying rods for a wall.

Table 2. Potential Hazard Zone Risk Factors and Solutions by Task for Re-bar Workers

*Indicates a recommended practice that may not be feasible in some cases or that may not reduce the risk factor below the Hazard Zone

Risk Factor	Possible Hazard Zone Tasks	Mitigating Solutions
Heavy Lifting > 90 lbs or > 70 lbs From Ground	Lifting re-bar rods	1) Use mechanical equipment such as cranes, forklifts or backhoes. 2) Get help from another worker if mechanical aid is not available. 3) Limit the number of rods lifted to 70 lbs from ground (see tables). 4) Limit the number of rods lifted to 90 lbs if they are raised from ground.
Back Bending > 45 Deg. More Than 2 Hrs/Day	Installing footing re-bar and deck or slab mats	1) Use a re-bar tying tool with handle extension (under investigation). 2) Tie sub-systems and columns on support stands.* 3) Try to rotate job activities when possible.*
High Hand Force w/Repetition and Awkward Posture > 2 Hrs/Day	Tying rebar	1) Use a re-bar tying tool at least part of the day (under investigation). 2) Try to rotate job activities when possible.*

Figure 13. Re-bar can be lifted by crane or forklift onto support stands that will raise the lifting height to knee level and increase the maximum acceptable lift to 90 lbs.

Figure 14. Support stands should be used for construction of components when possible to reduce back bending and other awkward postures.

Figure 15. Two workers can lift twice as many rods, or heavier rods when mechanical aid is not feasible.

Table 3. Acceptable Number of Re-bar Rods for a One-Person Lift from the Ground (70 lbs)

	Inch-Pound Bar #										
Length in Feet	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**14**	**18**
5	37	21	13	9	6	5	4	3	2	1	1
10	18	10	6	4	3	2	2	1	1	0	0
15	12	7	4	3	2	1	1	1	0	0	0
20	9	5	3	2	1	1	1	0	0	0	0
25	7	4	2	1	1	1	0	0	0	0	0
30	6	3	2	1	1	0	0	0	0	0	0

Table 4. Acceptable Number of Re-bar Rods for a One-Person Lift at Knee Level (90 lbs)

		Inch-Pound Bar #										
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**14**	**18**
Length in Fe	**5**	48	27	17	12	8	7	5	4	3	1	1
	10	23	13	8	5	4	3	3	1	2	0	0
	15	16	9	5	4	3	1	2	1	0	0	0
	20	12	7	4	3	1	2	1	0	0	0	0
	25	10	5	3	1	2	1	0	0	0	0	0
	30	8	4	3	1	1	0	0	0	0	0	0

Figure 16. Powered re-bar tying tools are available that can quickly tie re-bar matting and reduce exposure to high hand force and repetition with awkward postures in some applications.

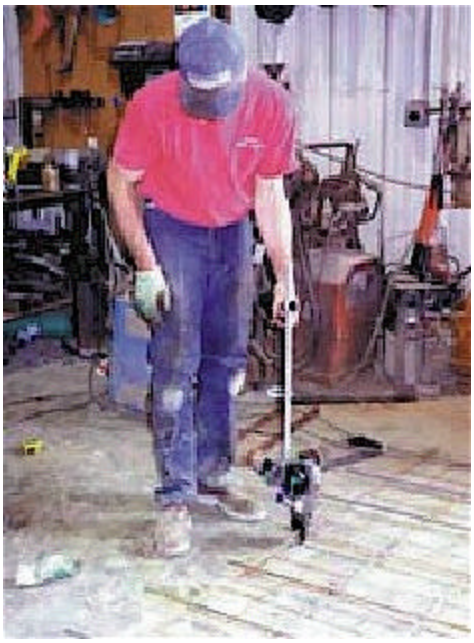

Figure 17. Re-bar tying tools can be used with a handle extension similar to that used on screw guns to reduce back bending duration.

Concrete Finishing

Concrete finishers were observed pouring slabs, decks and columns. Pouring columns did not present any Hazard Zone risk factors so this summary describes work done finishing slabs and decks. Typically the work was done in teams that rotated job tasks; however, this may vary from

between companies or teams. Regular tasks included the following: screeding, muck raking, vibrating, floating, power troweling, hand troweling, and pouring. The work methods observed at these sites did not contain Hazard Zone risk factors. However, powered trowels were used on both jobs and either regular rotation out of manual screeding or the use of powered screeds was also employed. The use of these tools and/or job rotation eliminated the presence of possible Hazard Zone risk factors. Without using these common practices, manual screeding and hand troweling would probably contain Hazard Zone risk factors if done regularly for the entire day.

Manual screeding involves bending over and scraping a 2x4 across the wet concrete to level the slab. This task would present back bending > 45 degrees for more than 2 hours per day as a Hazard Zone risk factor if done all day on a regular basis. Many companies currently employ either powered screeds or regular job rotation between screeding, muck raking, and troweling. Either of these approaches is adequate to reduce back bending below the Hazard Zone.

Hand troweling is limited by the use of either pushed or riding power trowels on most larger jobs. Troweling by hand would present kneeling greater than 4 hours per day as a Hazard Zone risk factor if done on a regular basis. No workers were observed doing this activity for a whole day due to the use of the powered trowels and job rotation. However, kneeling could be a Hazard Zone risk factor if these methods are not feasible for some reason. Back bending was not considered a Hazard Zone risk factor for this activity under the Ergonomics Rule because the workers were normally observed supporting themselves on a trowel in one hand while troweling with the other hand. Back bending would likely only be a Hazard Zone risk factor if only one trowel was used while hand troweling regularly all day.

Figure 18. A work team pouring and finishing a concrete slab.

Table 5. Potential Hazard Zone Risk Factors and Solutions by Task for Concrete Finishing

Risk Factor	Possible Hazard Zone Tasks	Mitigating Solutions
Back Bending > 45 Degrees for more than 2 Hrs/Day	Manual Screeding	1) Use powered screeds. 2) Regularly rotate between screeding and the other tasks.
	Hand Troweling	1) Use one trowel in each hand if done for more than two hours. 2) Rotate between hand troweling and the other tasks. 3) Use powered trowels where possible to reduce hand troweling.
Kneeling more than 4 Hrs/Day	Hand Troweling	1) Rotate between hand troweling and the other tasks. 2) Use powered trowels where possible to reduce hand troweling. 3) Provide padded knee protection if other solutions are not feasible.*

*Indicates a recommended practice that may not be feasible in some cases or that may not reduce the risk factor below the Hazard Zone

Figure 19. A powered screed removes back bending duration as a possible Hazard Zone risk factor for workers regularly screeding all day.

Figure 20. Powered troweling machines are typically used on commercial sites, which reduces the required hand troweling and possible kneeling as a risk factor.

General Findings for all Trades

Two risk factors: hand-arm vibration, working with the hands above the head were observed in activities on-site but not at levels approaching or above the Hazard Zone. However, these may be present in activities on other sites under some circumstances. Both risk factors appear to have easy controls that are already practiced or can be easily applied to current operations.

Hand-arm vibration above Hazard Zone levels may be present in high impact power tools used the majority of the day as a regular part of the job. The vibration level varies depending on the tool, manufacturer and even the condition of the tool in some cases. However, some tools of possible concern include: jack hammers, chipping hammers, roto-hammers, saws-alls, and re-bar saws. Compliance for a specific tool needs to be considered on a tool-by-tool basis; however, they should be considered if used for the majority of the day on a regular basis. If this is case for a job, provision of anti-vibration gloves will likely be appropriate as an interim control. Rotating workers out of the task is preferred over provision of gloves where possible to control exposure. Vibration-dampened tools are the preferred solution when available as an alternative. Feasibility of improved tools should be considered in future tools purchasing decisions where a worker may be at Hazard Zone level exposure.

Hand above the head or elbows above the shoulder must be present as a risk factor for more than 4 hours per day to become a Hazard Zone risk factor. This level is not observed very frequently, due to the physical demands of maintaining these postures. However, there may be some circumstances where this exists on job sites. Generally, proper use of lifts and scaffolds can mitigate this risk factor. Hand-crank and powered lifts are available to lift and hold material and equipment in place for most construction tasks. These eliminate hands above head postures to hold material. Proper positioning of lifts or scaffolds can control these postures when working on the ceiling or high walls. The workers should position themselves so that the work level is at or below the top of their heads. If a worker is performing detail work on a ceiling, the lift can be positioned with the top of the head at ceiling level so that having the hands above the head is not possible. In cases where a surface is being applied above the head, a combination of controlling worker heights and the use of tool handle extensions and/or spray guns can usually reduce the risk factor below the Hazard Zone level. In cases where these solutions are not feasible or the risk factor still exists, job rotation may be investigated as a possible solution. Figure 21 shows worker doing detailed ceiling work with the lift positioned so the top of the head is at the ceiling level.

Figure 21. Positioning of a lift with the top of the head at ceiling level can reduce hands above the head and elbows above the shoulders duration.